	G. M. T. h.	m.
Pitatus, N. W. border	11	35.1
Munosius	11	37.6
Aristarchus	11	50.1
Bessarion E.	11	52.1
Copernicus, center	11	56.1
Copernicus, outer edge of N. W. wall	11	57.1
Euler	11	58.1
Pytheas	12	0.3
Fracastorius, N. W. border	12	2.4
Sinus Iridum, bisected	12	5.1
Timocharis	12	6.1
Cape Laplace	12	8.4
Dionysius	12	11.1
Plato, E. border	12	13.1
Plato, W. border	12	16.0
Menelaus	12	16.8
Posidonius, N. W. wall	12	28.0
Proclus	12	29.9
Endymion	12	34.3

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THE EFFECT OF PARALLAX ON THE PHENOMENA OF THE SATELLITES OF *MARS.*

BY W. J. HUSSEY.*

In treating of the phenomena of the satellites of *Mars* as seen from the surface of the planet, it has been customary for popular writers to disregard parallax and in consequence some of their statements are considerably in error. Some of these errors have appeared in well-known text-books and especially on this account it is desirable to call attention to this subject.

For a popular statement it is sufficient to use approximate data and calculations. Refraction due to the atmosphere of *Mars* may be neglected. Not enough is known of the constitution of the atmosphere of *Mars* to enable the amount of refraction due to it to be even roughly estimated. But it is doubtless small in comparison with the other quantities which we are considering

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and, although its tendency is to counteract the effect of parallax, it may be neglected without much error. *Mars* is nearly spherical, its satellites move in ellipses differing but little from circles and in planes very nearly coincident with the plane of the planet's equator. Hence, for the present purpose, it may be assumed that *Mars* is spherical and 4230 miles in diameter, that the satellites move in circular orbits in the plane of the planet's equator, that *Phobos* is 5850 miles from the center of the planet and *Deimos* 14,650 miles.

As seen from the surface of the planet and from its center, the satellites will in general appear in somewhat different directions. This difference of direction is the parallax of the satellite, and its value is greatest, for a given distance of the satellite from the center of the planet, when the satellite is in the horizon as seen from surface. The above quantities give a horizontal parallax of 21°.2 for *Phobos* and 8°.3 for *Deimos*. Neither of the satellites can be seen at or near the poles of the planet. *Phobos* never appears above the horizon of places having latitudes higher than 68°.8. For *Deimos* the limit is 81°.7.

Mars rotates in $24^h\ 37^m\ 23^s$, its satellites revolve in $7^h\ 39^m\ 14^s$ and $30^h\ 17^m\ 54^s$. Their motions are all from west to east. Their hourly rates of movement are 14°.88 for *Mars*, 47°.04 for *Phobos* and 11°.88 for *Deimos*. Since *Phobos* revolves more rapidly than *Mars* rotates, it would to an observer on *Mars*, rise in the west and passing quickly across the sky, set in the east. *Deimos*, like all the other heavenly bodies, rises in the east and sets in the west. The interval from one rising to the next, or from one setting to the next, is found by dividing 360 by the difference of the hourly rates of *Mars* and its satellites. This gives for *Phobos* about 11 hours and for *Deimos* about 66 hours. The intervals from rising to setting are considerably less than half of these. For instead of remaining above the horizon during half a revolution about the center of the planet, or 180°, they remain above it less than this by twice the horizontal parallax. This for *Phobos* is 137°.6 and for *Deimos* 163°.4 and the times required to describe these arcs are about $4^h.3$ and $59^h.6$. These are respectively the intervals which *Phobos* and *Deimos* remain above the horizon of a place on *Mars*' surface.

The diameter of the shadow of *Mars* at the distance of *Phobos* is about 4195 miles and at the distance of *Deimos* 4140 miles. These values are variable since the distance from *Mars* to the *Sun*

is variable, their variations being some 5 and 10 miles respectively either way. These variations are slight and have very little influence on the values of the quantities we are considering.

The satellites of *Mars* are frequently eclipsed but not invariably when in the position of full moon. The inclinations of the planes of their orbits to the plane of the planet's orbit, are so great that during certain periods they regularly pass above or below the shadow and are not eclipsed. This is the case when the satellites are far from their nodes at the times of full moon. Otherwise they are eclipsed at every revolution. Thus *Phobos* is not eclipsed if more than about 58° from either of its nodes, nor *Deimos* more than about 19°. On the average *Phobos* is eclipsed about two out of every three times that it is in the position of full moon and *Deimos* about two out of every nine times.

The eclipses vary in length, being longest when the satellite is at one of its nodes when in the position of full noon, for it then passes centrally through the shadow of the planet. The maximum duration of an eclipse of *Phobos* is about 53 minutes, for *Deimos* it is about 84 minutes.

During a night on *Mars* an observer on that planet may at times have the opportunity of observing two total eclipses of *Phobos*, one in the evening and the other the next morning. For such an opportunity to occur, the planet must be near one of its equinoxes and *Phobos* must rise at or very nearly the setting of the sun. Suppose the planet at one of its equinoxes and *Phobos* to rise as the sun goes down. This will be at six o'clock in the evening on *Mars*. About 3.4 terrestrial hours later, or a little before half-past nine, the sun will be about 50° below the horizon and *Phobos* 50° east of the meridian. The eclipse will then be at its middle, the total phase having begun some 26 or 27 minutes earlier. In as many minutes more, the total phase will end, and somewhat more than half an hour after the end of the eclipse *Phobos* will set in the east. It will rise again very soon after five o'clock the next morning. But it will then be invisible, being at the time totally eclipsed. This eclipse will have ended more than half an hour before the rising of the sun, and at the end of the total phase *Phobos* will be 15° or more above the western horizon.